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EFFECTS OF HIGH SOIL AND AIR TEMPERATURES ON CERTAIN ALFALFA INSECTS

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When work was begun on alfalfa insects in 1920, it was soon observed that the insects increased in numbers on each growth from few on the stubble to large numbers at cutting time, which is near the tenth bloom stage. The winged species were seen to fly from the field when the crop was cut, but the question arose as to what happened to the great numbers of wingless forms left on the stubble. Some birds such as grackles, sparrows, robins, and domestic fowls were commonly seen in newly mowed alfalfa fields feeding on them. Insect predators also were seen feeding on some. It was discovered that a few immature forms found sufficient foliage on uncut plants and in the buds at the base of plants for survival, but repeated examinations of uncut plants and of stubble disclosed few surviving insects except grasshoppers.

Alfalfa is ordinarily harvested on dry, warm to hot, clear days during the summer when soil temperatures are high. Finding dead and dying insects, particularly caterpillars, on the hot soil indicated another little investigated cause of the decimation of alfalfa insects at cutting time. This paper is a report of field and oven tests with high soil temperatures conducted largely in 1926-1935 with green clover worms, alfalfa caterpillars, forage loopers, corn earworms, garden webworms, and others. Secondarily, observations are included on the relation of high air and plant temperatures to the behavior and distribution of these insects on the plants, air temperatures at different heights above the soil, and effects of solar heat on respiration and the heart beat.

REVIEW OF LITERATURE

Little published work dealing exactly with the type of high-soil-surface-temperature experiments described here has been found, but there is much literature dealing with the reactions of insects to temperature, control of insects by heat, and the general topic of climate and insects. Published high temperature observations deal principally with the cotton boll weevil, certain alfalfa insects such as the alfalfa weevil and alfalfa caterpillar, and sand dune insects.

Hunter (1912) pointed out that when cotton squares, infested by boll weevil larvae, fell to the ground, they became so heated that the larvae were killed in a few minutes. If the ground was shaded by rank growing plants or narrow rows, fewer larvae were killed. It had been observed that as high as

[1] Contribution No. 642, Department of Entomology, Kansas Agricultural Experiment Station, Manhattan. Results obtained in the course of work on Hatch Project No. 6 of the Agricultural Experiment Station.

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40% of the immature weevils were destroyed on the ground by heat. Where there was no shade, practically all the larvae and pupae were killed.

Hunter and Pierce (1912) stated further that field studies from 1906-1909 inclusive, indicated that there had been an average of 24.5 percent mortality of the cotton boll weevil resulting from climatic factors. Of the total natural control, 27 percent of the mortality occurred in the fallen squares. These authors also noted that wider rows favored control by heat and dryness. Also, fields with varieties of cotton with comparatively small amounts of leafage showed greater mortality as a result of heat and dryness. Percipitation reduced the soil surface temperature and weevil mortality.

These same authors also reported results of dropping live cotton boll weevils on the soil when surface temperatures were 110° to 140°F. No weevils were killed below 122°, but at higher temperatures they were killed by exposures of 1 to 900 seconds. From these tests the authors concluded that the upper zone of fatal temperatures ranged from 122° to 140°F. The relative humidity during these tests was 37 to 40 percent. The air temperature at 4 to 6 feet was 95°F. when the zone of fatal temperatures was reached.

Hunter (1917) suggested a cultivator device that would dislodge infested squares and adult weevils from the plant and cause them to fall to the ground where many would be killed by the heat.

Hunter and Coad (1922) stated that as many as 90 percent of the immature boll weevils in cotton fields were killed by heat when infested squares fell to the ground. The mortality was related to the extent the squares were subjected to the unobstructed rays of the sun.

Hamlin *et al.* (1949) stated that the first cutting of alfalfa reduced the larval population of the alfalfa weevil virtually to zero in 1 to 2 weeks (see their Fig. 11). Clear, hot weather was observed to favor larval mortality. Larvae crawled up stubs to escape the heated soil because of the difference in the temperature of the soil surface and aerial leaves. Removal of the plant growth resulted in an increase in the temperature of the field surface. Many larvae congregated under the haycocks to escape the stubblefield heat. Delay in removing the hay permitted some individuals to reach the adult stage and thus diminished the cultural kill. Prompt removal of the hay was necessary to gain the greatest benefit from the cultural kill. Earlier cutting and the consequent starvation of immature larvae gave heat cultural control.

Wildermuth (1914, 1922) stressed the importance of clean cutting to aid in the natural control of the alfalfa caterpillar because the young larvae could climb the uncut stems, escape the high soil temperatures, and feed in the foliage to maturity.

Packard and Campbell (1926) named death of pea aphids (*Macrosiphum pisi* Harr.) in California from extreme heat and low humidity as an important natural control of this pest. Piles of dead aphids were frequently seen in fields where there was little green vegetation to protect the aphids from the direct rays of the sun and the reflected heat from the ground.

Dudley (1935) pointed out that 80 to 95 percent of pea aphids died if jarred to the ground when the surface temperature was 120°F.

Wadley (1931) tested the green bug (*Toxoptera graminum*) for quickly fatal temperatures. He used a vial containing aphids on a leaf placed inside a

larger vial in a beaker of water gently heated and found that above 30°C. (86°F.) the aphids were restless; above 35°C. (95°F.) they often left the leaf and moved around frantically. Their movements were aimless at 41° C. (105.8°F.) and ceased at 42°C. (107.6°F.). None survived after 30 seconds exposure to 43°C. (109.4°F.). Nymphs were killed at 35°C., but 8 adults survived 16 hours exposure at this temperature.

Headlee and McColloch (1913) stated that as temperatures rise, metabolism in the chinch bug increases, later decreases, and finally stops altogether. Chinch bugs perished when knocked to the hot ground which was about 132°F. during the harvest of 1912. In oven tests, 19 out of 20 chinch bugs were dead in 24 hours at 98°F., all were dead in 60 minutes at 119.3°F., and in 30 minutes at 127.4°F.

Guthrie and Decker (1954) found that at about 50°C. (122°F.) an equilibrium point was reached where chinch bug mortality was the same regardless of relative humidity. At lower temperatures, survival was favored by low humidity. Dessication became progressively less important as the cause of death as the humidity and temperature increased.

Roan (1952) reported that the oriental fruit fly, *Dacus dorsalis* Hendel at 41°C. (105.8°F.) showed heat rigor and became prostrate. At temperatures above 43°C. (109.4°F.), a low humidity favored survival, whereas below 43°C. low humidities were inimical to the fly. At low humidities, the fly could maintain by evaporation a temperature slightly lower than the environmental temperature. This was demonstrated by thermocouple temperature determinations of living flies at zero and 100 percent humidities. The exposure time for 100 percent knockdown from heat rigor ranged from 20 seconds at 50°C. (122°F.) to 15 minutes at 43°C. (109.4°F.).

Miller (1931) reported that it has been known for many years that wood borers and bark beetles may be killed by heat absorbed by the dead host plant when exposed to sunlight. Bark removed from a log and exposed to the sunlight during midday will reach a temperature of 110° to 130°F. when the air temperatures are 80° to 95°F. A partial mortality of the broods results if bark temperatures range from 100° to 115°F. daily for several days. Complete mortality is assured if bark temperatures reach 115°F. to 118°F. for two hours or more. No broods survive a brief exposure if the temperature of the bark reaches a maximum of 120°F.

One of the early studies of the diurnal response of insects to soil temperatures was recorded by Chapman *et al.* (1926) from studies of sand dune insects. The highest sand surface temperature was 56°C. (132.8°F.) but might have been as high as 74°C. (165.2°F.) on a previous day. The authors used thermometers covered except their scales with a thin layer of sand and 10 thermocouples to determine temperatures. Their table of temperatures from 1 to 24 inches above the surface showed the highest temperature at the surface on clear days. When confined on the surface of the sand at temperatures of 47° to 56°C. (116.6° to 132.8°F.), most of the forms died in 3 to 12 minutes, but two velvet ants survived. Sand dune insects were not alike in their temperature adjustments.

Fife (1934) and some others have pointed out that the conditions measured by meterologists are not the conditions under which insects live. He

stated that air temperatures as recorded by a field thermograph do not give a true picture of the conditions under which an insect is developing.

Parker (1929) stated that "when the soil temperature reaches 45°C. (113°F.) both nymphs and adults (of grasshoppers) leave the ground and seek a more desirable temperature by climbing weeds and blades of grass." He pointed out that there is sometimes a difference of 40°F. between the soil surface and 2 inches above the ground. A grasshopper is able to choose its own temperature by merely moving 1 or 2 inches up or down a blade of grass. Nymphs and adults became excited and nervous when the temperature in rearing cabinets was held at 46°C. (114.8°F.). At 50°C. (122°F.), nymphs were still active after an exposure of 1 hour, but adults were in heat rigor after a 5-minute exposure; the nymphs recovered upon removal. At 55°C. (131.5°F.) nymphs were killed by a 5-minute exposure.

Mention will be made of only a few publications dealing with the control of certain insects by high temperatures. Dean (1911) noted that common mill insects died when exposed to temperatures of 105° to 120°F. for 4 or 5 hours per day for several days. Steam heating of flour mills over Sunday in summer became a regular control in flour mills and continued until largely replaced by fumigants and sprays in the early '30's. It was necessary to heat the accumulations of flour to about 118°F. and to continue the heating several hours. Air temperatures in heated mills frequently reached 160°F. during heating, but 125° to 135°F. temperatures were more common.

Back (1939) said that bean weevil eggs are killed when the beans are exposed to a temperature of 125.6°F. for 10 minutes; newly hatched larvae die in 7 minutes at 131°F.; full-grown larvae in beans die in 20 minutes at 131°F.; pupae die in 25 minutes at 131°F. and adults die after a 4-minute exposure at 131°F. To kill the southern cowpea weevil, the seeds must be exposed for 10 minutes to a temperature of 140°F. but in commercial treatments, 20 to 30 minutes at 146°F. was recommended. Exposures for 5 to 40 minutes at 120°F. to 140°F. did not kill the broad-bean weevil in broad or windsor beans, and higher temperatures injured germination.

Reppert and Bentley (1936) showed that in Texas when infested cowpeas were exposed to the sunlight on a clear day with no wind blowing between 10 a.m. and 4 p.m. when shade temperatures were 98°F. or more for 75 minutes, complete destruction of all weevils resulted. This interval could be reduced to 15 minutes if the infested cowpeas were in a glass-covered tray.

OBSERVATIONS MADE DURING THESE STUDIES

Here follows a report of a series of original temperature studies made on the hotter days in summer on some alfalfa insects. The first problem was to decide upon a satisfactory means of determining the temperatures of the surface of the soil, of plants at various heights, and of the insects on the plants.

METHODS OF FINDING THE TEMPERATURE OF THE SURFACE OF THE SOIL

Four methods for taking the temperature of the soil surface were tried.

I. Laying the thermometer on the surface of the soil in the sun.

II. Same but shading the bulb.

III. Covering the bulb thinly with fine, dry soil. (Chapman *et al.* 1926)

IV. Coating the thermometer bulb and stem with thin mud, allowing the mud to dry and placing on the surface of the soil in the sun.

Table 1 is a set of readings from matched centigrade thermometers used in these four methods.

TABLE I. Comparative tests of four methods of taking the temperature of the heated surface of the soil with Centigrade thermometers. Comparisons should be made horizontally.

Hour	Method I Ave. of 3 Readings	Method II Ave. of 2 Readings	Method III Ave. of 2 Readings	Method IV Ave. of 3 Readings
2:20	40	37.3	42.5	41.3
2:25	40	38.0	42.5	41.6
2:30	40.3	37.0	43.7	44.3
2:40	40.8	40.8	44.0	44.9
2:45	40.5	38.1	44.9	45.6
2:55	41.6	36.6	45.6	46.2
3:05	39.8	38.2	45.5	44.8

The first method does not preclude the effects of radiation which renders the readings inaccurate and unreliable. The second method consistently gave the lowest readings. The third and fourth methods gave the highest readings. Direct radiation and the rapid changing effects of the air are practically excluded in the third and fourth methods. Since these two methods are open to no serious criticisms, they were adopted for use during these investigations.

DETERMINING LENGTH OF SURVIVAL OF INSECTS ON THE HOT SURFACE OF THE SOIL

Observations on the effects of hot soil on alfalfa insects were made on small, especially prepared plots about 2 feet square exposed to the sun at the edge of a small alfalfa field. Immature stages of insects were obtained by sweeping alfalfa plants near by and dropping the insects singly onto the testing plot. The surface was devoid of vegetation or trash upon which an insect could crawl to escape the high soil surface temperatures. There was generally a thin layer of dust or loose soil particles on the plot.

Soil killing tests were made only at temperatures which would be lethal in at least 10 to 20 minutes. Too few tests could be made if temperatures requiring 1 to 2 hours to death were used. Individual tests were conducted in a continuing series. Clouds and cool breezes sometimes lowered the air and soil temperatures slightly, introducing temperature variables into the tests. In nature, all the insects in a field are exposed to the same air and soil temperatures together and the highest temperatures are the most potent.

Furthermore, the time to death of first and second instar larvae at the highest temperatures was generally too short to time with reasonable accu-

racy. Death in the smallest larvae and nymphs was almost instantaneous. It was often difficult to determine the exact death point of larvae.

The soil temperature was taken by the third method. In the earlier tests, Method IV was also used but it was discontinued because the readings were generally lower and more variable than by Method III. A third thermometer was always suspended in the shade nearby for taking the air temperature at intervals. Ordinary technical mercurial thermometers graduated in 2°'s F. or C. and matched closely by identical readings in jars of water at several high temperatures were used in the tests. Two persons were required to perform these tests, one manipulated the insects, the other kept time with a stop watch and made the records.

These soil surface killing tests included 310 green clover worms of which the records for 57 that revived were discarded, 98 alfalfa caterpillars of which 11 revived, 17 corn earworms none of which survived, 69 forage loopers of which 13 revived, 19 yellow-striped armyworms of which 6 revived, 8 geometers, 7 chinch bugs, and 3 arctiid larvae none of which survived. While this discussion deals only with tests in which death resulted, no doubt many that revived were so injured to cause death later or an imperfect adult.

INTERPRETATION OF THE BEHAVIOR OF THE INSECTS

When larvae were dropped on the soil, they usually fell in a flexed position. The first reaction to the heat was uncoiling. The "time to showing first effects which was generally uncoiling" was the first time-record made (Tables III, IV). The larvae would then begin to crawl hurriedly away, but when the direction became aimless and the larvae reached toward their posterior parts as if to bite what was causing them distress, a second time interval was recorded. This was the time "to showing serious effects or distress." Then the time "to dying" was recorded at which stage larvae were largely immobile and fell over on their sides. This indicated marked heat rigor. The posterior part of the body became quiet first but the mouth parts continued to move after the legs and body showed no movement. The mandibles were watched through a lens until all movement ceased and the time between being dropped and cessation of mandibular movement was recorded as the threshold of death indicated in Table II "to death." The tested larvae were then placed in salve boxes and stored in the field insectary 24 hours with food to determine whether any revived.

THE GREEN CLOVER WORM, *Plathypena scabra* (FAB.) SOIL SURFACE KILLING TESTS

The green clover worm is a common, delicate, light green caterpillar present throughout the growing season in alfalfa fields in Kansas. Since this caterpillar was generally the most abundant caterpillar in alfalfa, it was used most extensively in the tests.

The data in Table II confirm the fact that the soil in hot dry weather is hot enough to kill the active green clover worms in a short time. In general, the fourth instar larvae died in less time after being dropped on the soil at 143-145°F. than at 131-133°F. soil temperature. Furthermore, the time to death was in general longer for fifth instar larvae and still longer for the sixth or full grown larvae at both temperature ranges. The same relation is

TABLE II. Typical records of heat killing tests of fourth, fifth, and sixth instar green clover worms at two narrow soil temperature ranges 131-133°F. and 143-145°F. There is given in columns 1 and 3 the time to showing serious effects and in columns 2 and 4 the time from dropping on the hot soil to death. These soil temperatures occurred when the air temperatures at 4-5 feet were 100-103, and in the second case 101-108°F. The air humidity was 30 to 39 percent.

	Soil Temperature 131-133°F. Time from dropping on soil to:		Soil Temperature 143-145°F. Time from dropping on soil to:	
Instar	Showing Serious Effects	Death	Showing Serious Effects	Death
4th Instar	9″	33″	10″	24″
	23″	56″	11″	25″
Length	21″	1′01″	16″	27″
11-17 mm.	15″	1′05″	17″	28″
	11″	1′11″	19″	32″
	18″	1′11″	20″	35″
	26″	1′24″	27″	1′00″
	17″	2′17″	53″	1′38″
	14″	2′18″	22″	1′57″
			1′10″	2′40″
5th Instar	17″	54″	13″	28″
	25″	1′02″	22″	37″
Length	22″	1′09″	19″	38″
15-23 mm.	40″	1′10″	23″	38″
	18″	1′22″	20″	47″
	18″	1′45″	33″	53″
	19″	1′56″	39″	54″
	35″	2′10″	27″	58″
	21″	2′12″	22″	1′06″
	35″	2′15″	18″	1′07″
	19″	2′27″	1′00″	1′35″
	18″	2′35″	59″	2′00″
	30″	2′45″	24″	3′33″
	1′30″	3′00″		
6th Instar	17″	1′21″	37″	1′12″
	27″	1′28″	42″	3′04″
Length	14″	1′44″	1′09″	3′52″
20-30 mm.	25″	2′00″	1′30″	4′00″
	31″	3′26″	46″	5′40″
	1′10″	5′20″		
	28″	6′06″		
	1′15″	8′35″		
	20″	11′45″		
	14″	13′26″		
	1′10″	13′30″		

obvious for the time to showing heat rigor or serious effects from the high temperatures.

Such variation in killing time for larvae of the same species and size was largely unexpected. Noland (1944) stated that roaches from the same egg-sac and reared in the laboratory all died within a range of 0.3°C. regardless of their age or a "biological constant," but roaches captured at random showed a wider variation. He found the lethal temperature for all insects tested within the range of 45-55°C. (113-131.5°F.). He found the lethal temperature for grasshopper nymphs to be 53°C. (127.4°F.), while for cricket nymphs of corresponding weight and environment to be 48.5°C. (119.3°F.). The results with alfalfa insects agree with his random capture tests. Colleagues have suggested that it is reasonable to expect the same kind of variation in the reaction to lethal temperatures as is manifested against insecticides.

There is a question whether differences in the amount of water in the insect body could account for all the differences in survival time. It was thought that newly molted larvae might succumb more quickly than larvae about to molt so a test of this point was made. A scatter diagram (not included here) showed approximately the same amount of variation of fifth instar larval mortality at early, middle, and late stages in the instar.

TABLE III. Specimen data from exposure tests of various sizes of alfalfa caterpillars to hot soil surfaces, arranged according to soil temperatures 105°F. to 148°F. The time readings are cumulative and not differences. Uncoiling of larvae in all cases was immediate. ( ) indicates the instar.

Temp. Surface of Soil Covered	Larval Length mm.	Air Temp. Shade	Time to Showing Pronounced Effect	Time to Dying	Time to Death
105.8	21(5)	102.2	—	1″	2′20″
105.8	13(4)	102.2	2′40″	3′05″	4′51″
122.2	16(4)	99.8	35″	1′10″	8′50″
122.2	28(5)	99.8	3′20″	—	10′50″
127.4	16(4)	101.1	40″	1′10″	2′15″
129	20(5)	89.9	2′30″	12′20″	32′50″
136.4	16(4)	102.6	22″	40″	55″
136.4	12(4)	102.5	22″	35″	50″
136.5	25(5)	100.4	3′	5′	12′
136.5	7(3)	100.4	7′	45″	1′40″
137.1	23(5)	102.2	2′10″	—	15′40″
137.1	16′(4)	102.2	25″	3′40″	4′30″
137.4	25(5)	100.4	23″	70″	2′35″
140	19(5)	108	35″	1′10″	3′57″
140	18(5)	102.6	22″	42″	1′38″
140.1	14(4)	104.9	30″	—	1′25″
140.1	22(5)	104.9	20″	1′30″	3′20″
140.9	27(5)	103.5	35″	55″	10′
145.4	14(4)	104.9	15″	37″	1′11″
145.4	14(4)	104.9	40″	1′40″	2′15″
147.5	23(5)	111	32″	55″	3′25″
148	22(5)	111	1′10″	2′20″	5′17″
148	20(5)	111	15″	35″	3′15″
148	15(4)	111	15″	15″	3′15″
148	21(5)	111	5″	54″	4′35″

THE ALFALFA CATERPILLAR, *Colias philodice eurytheme* Bdvl., HOT SOIL TESTS

This common, green caterpillar of alfalfa fields lives normally high up on the plant, fully exposed even on the hottest days. The larva moves slowly and is not particularly delicate at any stage though highly susceptible in Kansas to a polyhedral disease.

Early in these studies, the chrysalids were found lying on the soil or in the stubble following cutting. Some of the chrysalids were injured mechanically and died. Adults with crumpled wings emerged from some. Both chrysalids and larvae were often found dead on the hot soil.

The relation of various sizes of alfalfa caterpillars to high soil temperatures follows the general pattern for the green clover worm. The longest time to showing pronounced effect (heat rigor), to dying and to death was generally not always longest for all instars at the lower temperatures nor for the larger larvae. The statement of Wildermuth (1914, 1922) that the alfalfa caterpillars die on hot soil was confirmed.

THE FORAGE LOOPER, *Caenurgina erechtea* (Cram.)

The forage looper is one of the common caterpillars present during the summer in alfalfa fields (Smith, 1924). The larvae are slender, striped, light green, active creatures which walk with a looping gait. Typical field soil surface heat tests are shown in Table IV.

There appeared to be less variation in the killing time of all stages even among the largest larvae of this species. The extremes of survival at lethal temperatures from all records were 45 seconds and 6 minutes compared with 30 seconds and 14 minutes for the green clover worm, but air temperatures during these tests were lower for the latter tests.

TABLE IV. Representative exposure test data with forage loopers on lethal soil surfaces, tabulated according to soil surface temperatures. Humidity 22 to 32 percent.

Soil Surface Temp.	Length mm. Instar ()	Air Temp.	Time to Uncoiling	Time to Showing Effect	Time To Dying	Time To Death
120.2	14(3)	100.8	10″	25″	45″	1′45″
120.2	30(5)	101	20″	30″	1′45″	6″
121	15(3)	101	2″	30″	1′15″	3′20″
121.3	25(5)	101	5″	40″	1′35″	2′
132	25(5)	103.6	5″	10″	25″	1′10″
134	15(3)	106	0	0″	20″	55″
134.6	15(3)	103	2″	5″	30″	50″
134.6	22(4)	103.6	1″	5″	20″	50″
134.6	24(4)	103.6	3″	5″	1′10″	2′25″
135.5	18(4)	97.5	0	10″	40″	3′50″
136.5	11(3)	100.4	0	5″	20″	50″

TESTS WITH OTHER SPECIES OF INSECTS

Tests were conducted with other species of larvae but the numbers were too small to justify including tables.

The corn ear worm *(Heliothis obsoleta* Fab.) occurs on alfalfa from May to November, but reaches largest numbers and does noticeable damage largely at the end of the season at which time soil surface temperatures are not lethal. The larvae are stout, hardy, active creatures which live fully exposed but these limited heat killing tests show them to succumb at rates comparable to those of the other kinds of caterpillars tested.

The garden web worm *(Loxostege similalis* Guen.) appears sporadically in alfalfa fields in Kansas attacking usually the second cutting. The larvae are soft bodied, delicate, and quite active. Remarkable variation in the dying time was indicated in the few tests run.

A few chinch bugs dropped on soil with surface temperatures of 130 to 138°F. died quickly. Nymphs were dead in 10 seconds to 1 minute while adults were dead in 1 to 1½ minutes.

COMPARISON OF KILLING ON SOIL IN AN ELECTRIC OVEN WITH HOT SOIL IN FIELDS

One kind of check on field killing tests was to drop larvae of various kinds and sizes on a pan of soil in an oven with temperature control and observe the larvae through the glass door of the oven. Soil temperatures of 120-150°F. were used. The records indicate that green clover worms 14 to 26 mm. long on soil at 120°F. and air temperatures of 120-123°F. varied from 15 seconds to 1 minute and 40 seconds to showing distress and 7 to 23 minutes to death. At 130°F. soil temperature and 131-133°F. air temperature, green clover worms 6 to 17 mm. long showed distress immediately to 15 seconds and died in from 50 seconds to 2½ minutes, while at 145 and 150°F. soil temperature and 146 to 154°F. air temperature, larvae 13 to 21 mm. long required from 1 to 8½ minutes to die. The data using alfalfa caterpillars and forage loopers indicate a similar high range of variations in time from uncoiling to death. While results are closely comparable to field data, timing periods in the four stages to death in general appeared to be a little longer in the oven tests.

OBSERVATIONS ON SAFETY ZONES

It is well known that when alfalfa is mowed on the hotter days, some immature, non-flying insects crawl up the stubble and rest on the shady side of the stub, Figs. 1-4. The question arose as to the difference in the temperature between the top of a stub, on the wilting hay and the surface of the soil.

An iron spike, a splinter of wood, some branches of alfalfa, bean, white top *(Erigeron* sp.), and milkweed *(Asclepias syriaca)* were placed upright in the ground in a fully exposed place. The height of each was approximately 2½ inches. The ground temperature was 136.4°F. and the air temperature 99.5°F. Alfalfa caterpillars, forage loopers, and green clover worms refused to stay on the spike and pine sticks, but came down in a few seconds where they succumbed to the hot soil temperature in from 3 to 15 minutes. However, other larvae rested comfortably on the green stems indefinitely unless disturbed by other larvae. Alfalfa and sweetclover stems were climbed more readily than were the others. Milkweed stems were distasteful apparently,

but the insects remained aloft. They came to rest almost invariably on the shady side of the stems. Caterpillars placed 6 inches distant in the shade where the soil temperature was 95°F. appeared to be unaffected by the heat for several hours. Larvae often came down the stems, reached out until they touched the heated soil surface, then retreated up the stem. Leaving the stem was fatal in a short time to the larvae in practically all cases.

TEMPERATURE AT VARIOUS LEVELS

The temperature at the surface of the soil exposed to the sun has been found to be consistently higher on the hottest days than the air temperature at any height above the soil surface between 1 and 24 inches. Table V is presented as typical of records on this point.

The first section of Table V records normal, summer temperatures with average sub-soil moisture. The figures indicate that the soil temperature was lower than the air at or above the top of alfalfa plants, but, in the case of the high temperatures recorded in the other section of the table, the soil under hotter and drier conditions was hotter than the air about it. There is, therefore, in these two series an overturn in the soil and air temperature relations comparable to the overturn in soil temperatures which normally occurs during the spring and fall. The air around the plants is cooler than at the soil surface in the summer and warmer than at the soil surface in the fall and spring. Insects, therefore, seek the tops of plants on hottest days to keep cool in the summer, but to be warmed up in the fall and spring.

A similar overturn in soil temperature was reported by McColloch and Hayes (1923). Mail (1930) mentioned briefly frequent overturns in the air temperatures from the soil surface up to 24 inches during fluctuations of the mean air temperature in November and December, but, if these fluctuations occurred when the mean air temperature was less than 0°C., the inversions did not take place. That author also pointed out that five times as much heat was required for dry soil. In average or heavy alfalfa growth, the surface of the soil is protected from the sun's rays and the soil is therefore not heated even to air temperature. The alfalfa growth referred to in the table was sparse and short due to dry, hot weather. The same trend of temperatures occurred there as occurred on bare soil.

It was found (Table VI) that the temperature of the soil surface was higher than some objects in an alfalfa field. The temperature of a good heat conductor such as a piece of galvanized iron may be lower than that of some poor conductors such as a board, stone, or alfalfa clump. This may appear surprising because the sensible temperature of good conductors generally appears higher than that of poor conductors. The actual temperature may be the reverse.

ORIENTATION OF LARVAE ON ALFALFA PLANTS WITH REFERENCE TO THE SUN

It was observed that when the species of caterpillars mentioned in the tests were placed on alfalfa stalks or on the ground near them when the air temperature was 100°F. or more, the larvae came to rest high up on the plants, partly or wholly in the shade of leaves or stems. Alfalfa caterpillars and green clover worms, as is their habit, were likely to rest on the stems or leaves in the sun or

TABLE V. Temperature at various heights from the surface of the soil to 24 inches above over bare soil in the sun and in heavy alfalfa growth, August 3, 1931, and on July 28, 1935. The temperatures were taken by matched centigrade thermometers suspended on a wood frame with the bulbs shaded and converted to Fahrenheit.

Time	3:30 P.M.	3:30 P.M.	4:00 P.M.	4:00 P.M.	4:30 P.M.	4:30 P.M.	5:00 P.M.	5:00 P.M.	1:30 P.M.	1:30 P.M.	2:30 P.M.	2:30 P.M.	4:00 P.M.	4:00 P.M.
Place	Over bare soil	In Alfafla Growth	Over bare soil	In Alfalfa Growth	Over bare soil	In Alfalfa Growth	Over bare soil	In Alfalfa growth	Over bare soil	In Alfalfa	bare Over soil	In Alfalfa	Over bare soil	In Alfalfa
Soil surface	88.7	87.8	88.7	86	87.8	86.9	87.8	85.1	110.4	112.1	109.4	107.6	105.8	103.1
2 inches above	88.7	87.9	88.7	86.9	88.7	86	87.9	86	107.7	109.0	107.9	106.1	104.0	102.2
4 inches above	89.6	88.7	89.6	87.8	89.2	86.9	88.5	86.9	107.7	107.6	106.7	105.8	104.0	102.5
6 inches above	89.8	87.8	89.4	87.8	89.6	87.6	87.8	86.9	108.5	105.4	104.4	104.0	103.6	102.5
8 inches above	89.8	87.8	89.2	86.9	89.8	87.8	88.7	87.8	107.6	106.7	104.9	103.2	103.1	98.6
10 inches above	90.7	86.9	89.1	86.9	89.2	87.8	87.8	87.1	107.6	106.7	104.9	103.2	103.1	98.6
12 inches above	91	89.6	89.4	82.4	89.2	87.8	87.9	87.8	107.6	104.5	105.3	102.5	102.5	99.8
18 inches above	90.7	90.1	89.6	87.8	89.2	87.6	87.9	86.9	109.0	107.6	109.6	104.9	103.4	100.7
24 inches above	89.6	90.5	89.8	87.9	89.6	86.1	89.2	85.6	106.8	107.6	107.9	106.1	104.9	100.7

partial shade. The forage loopers crawled to the under sides of leaves. Garden webworms crawled to the thicker foliage at the top or between two leaves close together.

Some kinds of larvae live on the upper side or at the edge of leaves, others live on the underside; some live in the upper part of plants, others live near the middle of the plant or in clumps of leaves. The question arose as to whether temperatures were factors in the distribution of larvae on a plant. Accordingly, some temperatures of the upper and lower sides of leaves and parts of alfalfa plants were taken with the thermocouple.

It is well known that crickets, many spiders, and beetles hide under stones, thus taking advantage of a poor heat conductor with a resulting moderation of their micro-climate.

Miller (1923) stated that "the temperature of turgid leaves of corn, sorghum, pumpkin, and watermelon in direct sunlight may fluctuate slightly above or below air temperature, but the average temperature of the leaves is approximately that of the surrounding air. In corn, the average of more than 1,000 determinations of leaf temperature under a wide range of conditions was 30.64°C., while the average air temperature for an equal number of determinations during the time was 30.58°C." Soybean leaves gave an average of 33.66°C. in 500 determinations with 33.13°C. for the air. The temperature at the base of a leaf is always lower than at the tip.

A portable thermocouple (Fig. 7) was built for these studies (Robinson 1927). One change in usual thermocouple technique was made for convenience—the water in the thermojug was tap water without ice, rather than the preferred melting ice which provides a somewhat better base temperature of 0°C. than cool tapwater. The necessary correction was readily made in the computations.

Only a few leaf temperatures were taken during these studies, but they corresponded to the findings of Miller for corn and soybeans. The differnces in the temperature of the upper and lower sides of alfalfa leaves were fractional generally and probably too small to be major factors in larval orientation on the plants. It is believed that in general the distribution of the insects observed on an alfalfa plant is prompted more by so called habit or to be near the most succulent leaves.

Grasshoppers, leafhoppers and similar forms quickly jumped to grass when placed on the bare soil test plots. These insects did not appear to suffer from the hot soil so much as caterpillars, whose bodies are nearer the soil surface. It is common knowledge that grasshoppers rest high upon vegetation even in trees during the hottest days (Figs. 1-4, 6). It was thought that some failures with bran mash sowings during the hot summer of 1936 were due to the fact that the hoppers refused, because of the hot soil, to descend from the tops of corn, weeds, fence posts and trees to feed on the poisoned bait. Dislodging them with a pole fastened at the proper height to a corn plow was tried and sometimes recommended.

It was also observed in 1938 that although Carolina grasshoppers flew up when disturbed and alighted generally in the sunny bare spots, if the soil temperature was 124°F.-132°F., they quickly moved to a shady spot.

TABLE VI. Comparative temperatures of different objects in an alfalfa field taken in Centigrade and converted to Fahrenheit degrees.

Date	Hour	Air Temp.	Temp. Soil Surface	Temp. Galvanized. iron cover	Temp. Clumps Severed bare Plants	Temp. Among Living Alfalfa Plants	Temp. of low thick Growth Alfalfa	Temp. of a board
July 9 1930	2:30	100.4	141.8	136.4	118.4	113.0		
July 9 1930	2:45	100.0	141	127.4	122	100.4		
July 23 1924	2:00	108	133	118	118	122.0	109.0	113
Aug. 6 1931	1:20	89.6	100.4	105.8	....	....		126.7

EFFECT OF HEAT ON LARVAL TEMPERATURES

Insects are cold-blooded animals, and are therefore, near the temperature of their immediate environments. Parry (1951) stated that the "temperature of Arthopods in sunlight is determined by the balance between radiative and convective heat exchanges, compared with which the heat associated with metabolism and evaporation is normally insignificant." The total mean radiation load per unit area will depend on the shape of the body and up to 50 percent by changes in orientation. The heating due to solar radiation is affected by color and there may be up to 50 percent in the total radiation load due to this factor alone. It is evident that determining the temperature of an animal in sunlight is very complex.

The temperature of some caterpillars was determined (Table VII) by pressing the thermocouple needle on the side of the body in furrows, or by insertion in the anus or the mouth. The temperature of the insect may be slightly higher or lower than the air or its substratum. It tends to be near the temperature of the plant upon which the insect is resting, but below the air and soil surface temperatures in hot weather.

It is difficult to draw conclusions from the data in Table VII except that differences are small and inconsistent. Averages for the forage looper larval temperatures were 86.2; air temperatures, 86.8; plant temperatures, 84.4.

A forage looper (not included in Table VII) was 0.2°F. cooler than the air temperature when the looper's temperature was taken by placing the needle in the folds of the cuticula at the side of the abdomen. Another of the same species on the same day was 0.6°F. hotter than the air temperature. An alfalfa caterpillar in an air temperature of 73°F. showed 76.9 mouth temperature, 74.6 anal temperature. When it was dead, the temperature was 74.7°F.

THE EFFECT OF HIGH TEMPERATURES ON THE RATES OF RESPIRATORY MOVEMENTS AND PULSATIONS OF THE DORSAL VESSEL OF SOME ALFALFA INSECTS

The usual well-known text books on insect physiology (Uvarov, 1931, Wigglesworth, no date) indicate that activity and temperature are two of the causes of variation in respiration and heart beat in insects. Few counts at high temperatures of either of these factors could be found in the literature.

In the case of green clover worms, the contractions of the dorsal vessel are

TABLE VII. Larval temperatures taken by pressing the needles of a thermocouple in folds of the cuticula on the sides of larvae on alfalfa plants in the field laboratory in July and early August. Each temperature is the average of 4 to 6 readings.

Kind of Larva	Temp. of Larva °F	Air Temp.	Temp. of Plant	Temps. by Other Methods
Forage looper	78.7	77.7	77.4	83.3 by anus
" "	103.5	109.1	106.8	contact
" "	83.6	83.2	82.3	"
" "	87.4	87.7	....	"
" "	88.3	88.2	....	87.6 by anus
" "	77.7	78.8	77.4	contact
" "	82.3	85.8	80.4	"
" "	88.7	88.1	....	87.6 by anus
" "	88.3	86.3	....	contact
" "	83.6	83.4	82.3	78.0 by anus
Gr. Clover Worm	97.9	98.9	106.8	
" " "	98.9	95.5	....	98.1 by anus
Alfalfa Caterpillar	75.7	73.0	73.4	
" "	75.4	64.8	74.2	77.5 by mouth 76.3 by anus

plainly visible under low magnification near the posterior end of the larva. The rate of contractions varied, but this variation was independent of length in larvae measuring 15 to 26 mm. The vessel contracted 115 to 130 times per minute with a larva at rest in an open glass tube at 96°F. and 53 percent humidity in the field insectary.

Another green clover worm, 23 mm. long, at a temperature of 95°F. in the field insectary showed 106 heart beats at the start, but over a period of observation when the temperature declined to 90.5°F., the heart beat varied from 96 at complete rest to 106 following activity. Another green clover worm 16 mm. long at 98.6°F. in the field insectary varied from 144 following activity to 111 when at rest.

After exposing larvae to killing temperatures, the heart beat was much faster. Counts of 136 to 173 contractions of the dorsal vessel were made of larvae seriously affected by soil surface temperatures of 130 to 134°F. The number of convulsive movements at the sides, posteriorly, were the same as heart beats. These were thought to be respiratory movements. The number of heart beats in the unexposed larvae was different every few minutes, so the count should not be interpreted as the "normal" rate for these species at the stage studied.

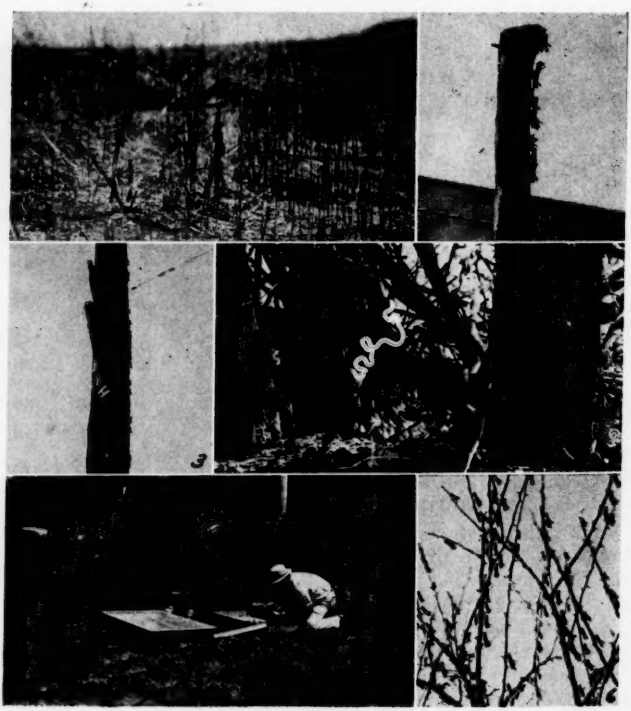
PRACTICAL APPLICATION OF THE KILLING TEMPERATURES OF SOIL SURFACES

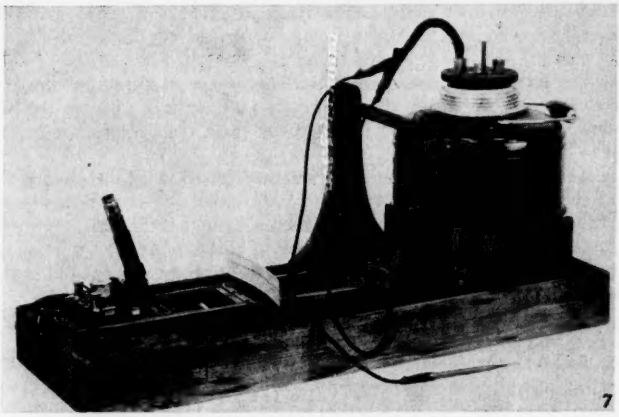
These studies were made only on hot days when temperatures were abnormally high and the humidity and soil moisture were much lower than during normal growing conditions. It was surprising to observers during these studies how quickly heat rigor developed in insects on the ground and that so many of the insects died in such a short time.

When alfalfa is cut for hay, some non-flying insects ascend the stubble in hot weather and escape the hot surface temperatures. Some burrow into the soil or go under trash for protection. Some migrate, but a considerable portion

of the insect population soon succumbs to the heated soil and to starvation. Others survive the temperatures for a while in one way or another but succumb eventually to dessication. Thus cutting the alfalfa for hay is actually an important insect control measure. Dead insects are readily found on the hot ground in alfalfa fields following cutting, but never in the numbers which apparently succumb from the cutting considering the almost total reduction in insect populations following cutting. However, actual counts on plots in fields unfortunately have never been recorded.

Mention has been made of chinch bugs being killed when jarred onto the hot soil from plants and when their migratory wanderings led them too far from safety zones. It was also observed that when pea aphids were jarred from plants or were swept off a chain drag to the ground at soil temperatures of 110° to 120°F. most of the aphids died before they could crawl back onto the plants. This has been a factor in the degree of control by mechanical devices. Most of the aphids were unable to go even a few inches to safety. This is a practical control for any field or garden species of aphids which drop readily when disturbed during the hot weather.





EXPLANATION OF FIGURES

1. Grasshoppers on defoliated oats plants on a hot day. Photo, E. G. Kelly.
2. Grasshoppers resting on the shady side of a post and on the wires during the heat of the day in mid-August, 1936, in south-central Kansas when the temperature was above 100° F. Photo, Dr. R. H. Painter.
3. Grasshoppers on the shady side of a telephone pole and on the wires. Conditions as above.
4. Grasshoppers resting on the shady side near the base of defoliated Osage orange trees. Conditions same as 2.
5. The late R. R. Reppert killing insects in cowpeas in shallow glass-topped boxes set in the sun in Texas, 1936. Photo, courtesy of R. R. Reppert.
6. Grasshoppers resting high up on the defoliated branches of Osage orange. Same as 2. Note the raised position of the hoppers.
7. The specially designed portable thermocouple used in these studies.

CONCLUSIONS

The following conclusions from the data obtained in these studies correlated with field observations appear to be justified.

1. Dry soil during the summers in Kansas reaches temperatures that are lethal in varying lengths of time for insects that are dropped or fall from plants. This is one of the causes of the destruction of insects in alfalfa when it is cut for hay.

2. There was considerable variation in the survival time of several kinds of caterpillars in alfalfa when subjected to lethal soil temperature. The variation increased as the larval length increased. This variation in killing time appeared not to be associated with the stage in the instar, i.e. following molting, near to the next molt, or midway in the instar, but with the species of larva. There was no evidence that death from heat for the instars of the various species at a given temperature was a biological constant, except that the time to death was in general shorter as the temperatures rose.

3. If larvae climbed up a stubble or plant, they survived lethal soil temperature indefinitely in hot weather, though they were only a few inches above the surface of hot soil. When placed on the bare ground, they succumbed to

the heat in from 30 seconds to about 5 minutes. Some insects in alfalfa fields apparently survive by climbing up plants when the alfalfa is cut. They generally seek the shady side of the stems.

4. The lower the temperature in the lethal range (120-130°F.) the greater the variation of the killing time for the larger larvae in general; the higher the temperature (145-160°F.) the narrower the range of variation in killing time.

5. The surface of the soil is the hottest place in fields during a hot day. The temperature of the air immediately above is lower, and the air temperature falls as the distance from the soil increases up to 24 inches.

6. Good heat conductors do not show so high a temperature by means of thermometers as do poor conductors. A metal screen cage was cooler than a board in the sun. Alfalfa plants were cooler than the air.

7. Insects when placed in the shade on the ground were not visibly affected, though they were quickly killed in the sun.

8. Field observations indicated that grasshoppers sought the shady side of poles and plants, including trees, on the hottest days, that they rested high up on defoliated vegetation with bodies raised probably for better aeration, and that when they landed on hot bare soil, they quickly jumped to a cooler location.

9. During cool periods in the summer, the soil temperatures were cooler than the air temperatures at or slightly above alfalfa plants, but during high temperature periods the soil was hotter than the air temperatures. Alfalfa insects seek the tops of the plants on the hottest days to keep cooler, but on cooler days in the fall and spring to keep warmer.

10. Because the temperatures on the upper and the lower surfaces of the leaves differ but slightly, the differences in location on the leaves of the various species studied are believed to be primarily differences in choice of foliage.

11. Larval temperatures may be slightly lower or higher than air temperatures. Activity caused an increase in heart beat, respiratory movements, and body temperature. Thermocouple temperature readings of larvae by contact with the sides, by mouth and by anus indicated different results, but no method gave consistently higher or lower readings.

12. Death of non-flying insects from heat is obviously one of the important causes of decline in numbers in alfalfa following mowing. Dislodging of wingless, slow-moving insects from plants is a common cause of death from contact with the hot soil not only in alfalfa fields, but in other crops.

LITERATURE CITED

Back. E. A. Jan. 1939. Weevils in beans and peas. U. S. Dept. Agr. F. B. 1275, 36 p.

Chapman, Royal N., C. E. Mickel, J. R. Parker, G. E. Miller, and E. G. Kelly 1926. Studies in the ecology of sand dune insects. Ecology 7:416-426.

Dean, George A. Apr. 1911. Heat as a means of controlling mill insects. Jour. Econ. Ent. 4:142-161.

Dudley, J. E., Jr. 1935. Preliminary experiments in the control of the pea aphid in the Northwest. Canning Trade 57(40):20-22.

Fife, L. C. July 1934. Temperature studies in a cotton field. Ecology 15(3):298-305.

Guthrie, F. E. and G. C. Decker. Oct. 1954. The effect of humidity and other factors on the upper thermal death points of the chinch bug. Jour. Econ. Ent. 47(5):882-887.

Hamlin, J. C. et al. July 1949. Field studies of the alfalfa weevil. U. S. Dept. Agric. Tech. Bull. 975, 84 p.

Headlee, T. J. and J. W. McColloch. Nov. 1913. The chinch bug. Kansas Agr. Exp. Sta. Bull. 191:287-353.
Hunter, W. D. Oct. 1912. The boll weevil problem. U. S. Dept. Agric. F. B. 512. 45 p.
Hunter, W. D. and W. D. Pierce. February 1912. The Mexican cotton boll weevil: a summary of the results of the investigation of this insect up to Dec. 31, 1911. Senate Doc. 305, 62nd Congress. 188 p.
Hunter, W. D. Aug. 1917. The boll weevil problem. U. S. Dept. Agric. F. B. 848. 40 p.
Hunter, W. D. and Coad. Feb. 1922. The boll-weevil problem. U. S. Dept. Agric. F. B. 1262. 31 p.
Mail, G. Allen. 1930. Winter soil temperatures and their relation to subterranean insect survival. Jour. Agr. Res. 41 (8):571-592.
McColloch, J. W. and W. P. Hayes. 1923. Soil temperature and its influence on white grub activities. Ecology. 4(1):29-36.
Miller, Edwin C. Oct. 1923. Some observations on the temperature of the leaves of crop plants. Jour. Agr. Res. 26(1):15-43.
Miller, J. M. Aug. 1931. High and low lethal temperatures for the western pine beetle. Jour. Agr. Res. 43(4):302-221.
Noland, Jerre L. Dec. 1943. An improved method for the determination of the lethal temperature of insects. Proc. Indiana Acad. Sc. 53:186-187. (1943). 1944. Abstract Anat. Rec. 87:260.
Packard, C. M. and Roy E. Campbell. 1926. The pea aphid as an alfalfa pest—California. Jour. Econ. Ent. 19(5):752-761.
Parry, D. A. 1911. Factors determining the temperature of terrestrial arthropods. Jour. Exp. Biol. 28(4):445-462.
Parker, J. R. 1929. Some effects of temperature and moisture upon the activities of grasshoppers and their relation to grasshopper abundance and control. Trans. Fourth Internat. Congr. of Ent. (Ithaca) 2:322-332.
Reppert, R. R. and M. R. Bentley. 1936. The practical use of the sun in cowpea weevil control. Kans. Ent. Soc. Jour. 9(4):126-139.
Roan, C. C. Dec. 1952. Reactions of oriental fruit fly to high temperatures and various relative humidities. Jour. Econ. Ent. 45(6):920-925.
Robinson. William. 1927. The thermocouple method of determining temperatures. Ent. Soc. Amer., Annals, 20(4):513-521.
Smith. Roger C. 1924. *Caenurgia erechtea* (Cram.) (Noctuidae) as an alfalfa pest in Kansas. Jour. Econ. Ent. 17:312-319.
Uvarov, B. P. 1931. Insects and climate. Ent. Soc. London, Trans. 79:247.
Wadley. F. M. 1931. Ecology of Toxoptera graminum especially as to factors affecting importance on the northern U.S. Ent. Soc. Amer., Annals. 24 (2):325-395.
Wildermuth, V. L., 1914, 1922. The alfalfa caterpillar. U. S. Dept. Agric. 124. 40 p. I.d. F. B. 1094, 16 p.
Wigglesworth, V. B. (No date). The principles of insect physiology, N. Y. Dutton, 434 p.

LECTOTYPES OF AFRICAN CHLOROPIDAE (Diptera) DESCRIBED BY C. F. ADAMS

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In 1905 (Kansas Univ. Sci. Bull. 3:149-208), C. F. Adams published a paper entitled "Diptera Africana, I" on the flies collected at Salisbury, Southern Rhodesia, by Frank L. Snow. Included were sixteen species of Chloropidae (including *Rhodesiella tarsalis*, described in Agromyzidae), of which ten were described from more than one specimen but without designated holotype. Lectotypes were selected by me several years ago, and five of these were published in 1951 ("Ruwenzori Expedition, 1934-5," British Museum (Nat.

Hist.), vol. 2, no. 7, Chloropidae, pp. 711-828). The remaining lectotypes are published herewith in order to complete the treatment of Adams' African species, to clarify the status of one with a mixed series, and to make the designations formally available for a forthcoming list of types and lectotypes in the Snow Entomological Museum at the University of Kansas.

The entries are arranged as follows: Scientific name as given by Adams; page number in Adams (1905); present combination, or the senior synonym; data on types and labels; notes on the species. All specimens are labeled "Salisbury, S. Africa, F. L. Snow, 5050 ft.," and that information has not been repeated in each case.

Oscinis basilaris Adams (p. 192)=*Oscinella basilaris* (Adams). Lectotype male and lectoallotype, both "Oct. 1900." This species was included in Becker's revision of the Ethiopian Chloropidae (1910, Ann. Mus. Nat. Hungarici 8:433-434) only from the description, and it cannot be placed in his key. It is very close to *Elachiptera* (*Melanochaeta*) *vulgaris* (Adams) and *E.* (*M.*) *scapularis* (Adams), differing chiefly in having a slender arista. Perhaps it should be transferred to that group, in spite of the aristal character, but the whole generic classification of the family needs careful study, and any transfers will be reserved for that more appropriate study. Brief diagnosis: head chiefly yellow; frontal triangle polished black, the ocellar tubercle and basal corners of triangle heavily gray pollinose; third antennal segment and arista black, basal antennal segments reddish-yellow; thorax black except for reddish humerus, propleuron, and under side of scutellum (as in *scapularis*); mesonotum, scutellum, and most of meso- and pteropleuron gray pollinose, lower pleuron and postscutellum polished; legs yellow. Eye pubescent; arista slender, pubescent; two strong and one weak orbital bristles; ocellar and post-vertical bristles erect and cruciate; notopleurals 1+2, but upper posterior bristle so weak that the notopleurals appear to be 1+1; wing venation as in *vulgaris*.

Meromyza opaca Adams (p. 193) = *M. capensis* Loew. Lectotype male and lectoallotype, "Oct., 1900," and 57 lectoparatypes (15 ♂ ♂, 21 ♀ ♀ of October 1900, 5 ♂ ♂, 1 ♀ of June 1900, and 2 ♂ ♂, 13 ♀ ♀ of May 1901), all of the May specimens and twelve of October labeled "in swamp." The legs are predominantly infuscated in most of the specimens, only a few having yellowish legs. I agree with Becker on the synonymy with *capensis*.

Pachylopus proxima Adams (p. 194) = *P. proximus* Adams. Lectotype male, lectoallotype, and 63 lectoparatypes (27 ♂ ♂, 36 ♀ ♀), all October 1900 and all but 15 lectoparatypes labeled "in swamp."

This is a common and well-known African species. The type series is uniform, without a single specimen of *punctifemur* Sabrosky, originally described as a variety of *proximus* and later raised to specific rank.

Pachylophus varipes Adams (p. 195) = *P. varipes* Adams. Lectotype male, lectoallotype, and three female lectoparatypes, all "May 1901, in swamp."

Pachylophus fossulata Adams (p. 195) = *P. fossulatus* Adams. Lectotype male, lectoallotype, and 10 lectoparatypes (6 ♂ ♂, 4 ♀ ♀), all "May 1901, in swamp." Typical *fossulatus* is distinguished from all other species of *Pachylophus* by the form of the frontal triangle, which has a deep circular depres-

sion immediately anterior to the median ocellus and a similar depression in the anterior third of the triangle, the two depressions separated from each other by a narrow ridge. Three cotypes which have the single median depression noted by Adams as an occasional variant, are really a different species, possibly a variant of *P. halteratus* Becker.

THE MENOPONIDAE (MALLOPHAGA) FOUND ON NORTH AMERICAN SWIFTS

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Public Health Service
Department of Health, Education, and Welfare
Atlanta, Georgia

Biting lice in the genera *Dennyus* and *Eureum* are found only on the swifts. The genus *Dennyus* was reviewed recently by Mr. M. A. Carriker. Notes on those forms of the North American species which were not available to Mr. Carriker for his review are presented here; as well as a description of one new species. The genus *Eureum* is extremely rare; illustrations of the one North American species previously known are presented, and one new species is described.

Genus *Dennyus* Neumann

Nitzschia Denny, 1842 (*nec* Baer, 1827). Mon. Anopl. Brit.; p. 230.
Dennyus Neumann, 1906. Bull. Soc. Zool. Fr., *20*: p. 60. *Nomen novum* for *Nitzsch'a* Denny, 1842 (*nec* Baer, 1827).
Dennyus Neumann. Ferris, 1916. Canad. Ent. *48*: p. 309.
Takamatsuia Uchida, 1926. J. Coll. Agri. Tokyo, *9*: p. 32.
Dennyus Neumann. Ewing, 1930. Proc. U. S. Nat. Museum, *77*, no. 2843: p. 2.
Ctenodennyus Ewing, 1930, Ibid: p. 9.
Dennyus Neumann. Buttiker, 1954. Acta Tropica, *11*: p. 159.
Dennyus Neumann. Carriker, 1954. Proc. U. S. Nat. Museum, *103*, no. 3331: p. 533.

Genotype: *Dennyus hirundinis* (Linnaeus), found on the European Swift, *Apus apus apus* (Linnaeus).

The genus is distinguished by its slender form. Antennae relatively small; antennal fossae partly roofed by an expansion of the head; no preocular notch or slit; eyes double, the two corneas on one side being partly fused; temples slightly expanded, angular; the occiput slightly concave.

Prothorax rather narrow, pronotum expanded laterally; prosternal plate well developed with heavy chitinous margin bearing more than two setae. Mesothorax small but distinct and separated from the metathorax by a distinct dorsal suture. First pair of legs short, second and third pairs longer; first femur very short, frequently as broad as long; hind femur very long, with a patch of setae on ventral surface.

Abdomen long; paratergites each with a marginal row of spines and a tuft of long hair-like setae; tergites bare except for a single transverse row of setae on the posterior margin. Abdominal sternites V and VI each with a

patch of fine setae in the posterior lateral angles. Abdominal sternite VII may have extra setae in the posterior lateral angles, but not a distinct patch as found on V and VI.

Genital armature of the male symmetrical, with long, narrow basal plate; parameres free, clasper-like, extending beyond preputial sac. Female genital region with sternites VIII and IX fused into a single large plate; the margin of the vulva smoothly convex with a corona of fine setae.

Previous authors have noted that the male genitalia are of little value in the separation of species in this genus. The chaetotaxy and the shape of the gular plate and thoracic sternal plates offer the best means for separation, especially for the forms found in North America. The thoracic prosternal plate of the male of each species has been illustrated, the figures being of the same scale, to show these differences. The gular plate is described for each species.

KEY TO THE NORTH AMERICAN SPECIES OF *DENNYUS*

1. Some of the setae on head and body short and peglike; each abdominal tergite bearing a posterior marginal row of normal setae alternating with short peglike spines (on *Nephoccetes niger borealis*) ..... *Dennyus spiniger* Ewing.
   Setae of head and body normal, none peglike 2
2. Gular plate with four medium length setae in clear portion of each lateral margin (on *Aeronautes saxatilis saxatilis*) ..... *Dennyus bruneri* (Carriker).
   Gular plate with two long setae in clear portion of each lateral margin 3
3. Fourth paratergites each with seven short spines (on *Chaetura vauxi*) ..... *Dennyus vauxi* n. sp.
   Fourth paratergites each with nine short spines (on *Chaetura pelagica*) ..... *Dennyus dubius* (Kellogg).

Dennyus bruneri (Carriker)

(Figure 7)

Nitzschia pulicaris var. *tibialis* Carriker, 1902. J. New York Ent. Soc. *10*: p. 225, pl. 22, figs. 4 and 5.

Nitzschia bruneri Carriker, 1903. Univ. Stud. Nebraska, *3*: p. 177.
Nomen novum for *N. tibialis* Carriker, 1902 (*nec* Piaget, 1880).

Type host: *Aeronautes saxatilis saxatilis* (Woodhouse), Whitethroated Swift.

Carriker has in his collection two males of the type series of this species. He did not know the location of the remaining male and female of this series, but stated: "If they still exist they should be considered as the male holotype and female allotype of the species." These two specimens are in the collection of Stanford University. As has been noted by Carriker, in his review, the gular plate is long oval-shaped and contains four medium-length setae inside the clear portion of each lateral margin. The prosternal plate may possess eight, nine or ten setae (Figure 7). There is some variation in location of the median setae, but apparently no variation in the size or shape of the plate. Figure 7 is from a specimen collected in Arizona.

In addition to the types, specimens were examined which had been col-

lected from the type host in Tucson, Arizona; Yosemite National Park, San Benito County, San Bernardino County and Coachella, California; and Golden, Colorado. The material from San Bernardino County, California, was determined by Ewing (1930, p. 8) as *D. dubius*.

Dennyus dubius (Kellogg)

(Figures 1, 2, 2A, 6)

Nitzschia dubius Kellogg, 1896. Proc. California Acad. Sci., 6: p. 540, pl. 73, fig. 6.

Type host: *Chaetura pelagica* (Linnaeus), Chimney Swift.

Material of this species was not available to Carriker for his study. The types are in the collection of Stanford University. The gular plate is short oval-shaped and contains two long setae just inside the clear portion of each lateral margin, and has two long setae outside of each posterior lateral and one outside of each anterior lateral angle. The prosternal plate may possess four or five setae, but six appears to be more normal. The prosternal plate illustrated in figure 6 is from a specimen collected in Georgia. Illustrations of both sexes have been furnished by Mrs. Chester J. Stojanovich and are shown in Plate I.

In addition to the types, specimens were examined which had been collected from the type host in State College, Mississippi; Lincoln, Nebraska; Rome, Georgia; New Platz, New York; Doroville, Oregon; Kansas City, Missouri; Urbana, Illinois; Massachusetts; Maryland; North Dakota; New Jersey; Pennsylvania; South Carolina; Virginia; Tennessee; and Indiana.

Dennyus spiniger Ewing

(Figure 8)

Dennyus (*Ctenodennyus*) *spiniger* Ewing, 1930. Proc. U. S. Nat. Museum, 77, no. 2843: p. 9, figs. 4 and 7d.

Type host: *Nephoecetes niger borealis* (Kennerly), Northern Black Swift.

Material of this species was not available to Carriker for his study. Ewing's description was based on a single female, which is now in the U. S. National Museum (no. 42762). Dr. G. J. Spencer, University of British Columbia, recently collected a series of this species which was loaned to the authors for this study.

The male is similar in shape and chaetotaxy, except for the terminal abdominal segments, to the female. The male ganitalia is not distinctive. The gular plate is short oval-shaped and contains three long setae just inside the clear portion of each lateral margin, two long setae outside each posterior lateral angle, and two short spines on the anterior margin. The prosternal plate may possess ten to fourteen stout spines and two or four long setae. There is considerable variation in the location of these setae and spines. The prosternal plate illustrated in figure 8 is from a specimen collected in British Columbia.

In addition to the type, from Seattle, Washington, specimens collected in British Columbia were examined.

Dennyus vauxi n. sp.

(Figures 3, 4, 5)

Male. As illustrated in figures 3, 4 and 5. Gular plate short, oval-shaped

and contains two long setae inside each anterior lateral angle, and two long setae outside each posterior lateral angle. Prosternal plate with eight setae (only one specimen was examined that possessed seven).

Female. Much larger than the male, total length being 2.82 mm. General shape and chaetotaxy, except for the terminal abdominal segments, same as for the male. Tergite VIII with four long and six short setae on the posterior margin. Vulva broadly rounded with twenty small setae on the posterior margin. Posterior margins, both dorsal and ventral, of anal corona with a thick fringe of small setae.

Type host: *Chaetura vauxi* (Townsend), Vaux's Swift.

Type material: Holotype male and allotype female were collected at Ft. Lowell, Arizona, on August 10, 1938, by Dr. Allan R. Phillips and will be deposited in the U. S. National Museum. Paratypes of the same series are in the collection of the University of Arizona. Nine paratypes collected at Santa Barbara, California, from the same host, are in the collection of Stanford University.

This species is closest to *D. dubius,* but differs in having a great number of setae on the prosternal plate and fewer spines on the paratergal plates.

Genus *Eureum* Nitzsch

Eurcum Nitzsch, 1818. Germar's Mag. Ent., *3*: p. 301.
Eureum Nitzsch. Ewing, 1930. Proc. U. S. Nat. Museum, 77, no. 2843: p. 10.
Arndtiella Eichler. 1948. Naturwissenshaftlichen Rundschau, *2*: p. 81. *Nomen novum* for "*Eureum* Ewing, 1930" (*nec Eurem* Nitzsch, 1818).

Genotype: *Eureum cimicoides* Burmeister, 1838, found on the European Swift, *Apus apus apus* (Linnaeus).

The genus is distinguished by its large, short, robust form. Antennae relatively small; antennal fossae partly roofed by an expansion of the head; no preocular notch or slit; eyes double, the two corneas on one side being partly fused; temples greatly expanded, angular; the occiput deeply concave.

Prothorax enlarged, emarginate laterally and posteriorly; prosternal plate well developed with heavy chitinous margin and bearing numerous setae. Mesothorax short, separated from the metathorax by a distinct dorsal suture, but seldom visible dorsally. Metathorax large, lateral margins expanded posteriorly. First pair of legs short, second and third pairs longer; first femur very short; hind femur has a patch of fine setae on the ventral surface.

Abdomen short and broad; paratergal plates each with a marginal row of spines and setae and a small tuft of long hair-like setae; tergites bare except for a single transverse marginal row of closely set setae. Abdominal sternites V, VI and VII have a patch of fine setae in each posterior lateral angle.

Genital armature of the male symmetrical, with short, wide basal plate; parameres short, clasper-like and free, extending beyond preputial sac. Female genital region with sternites VIII and IX fused into a single short plate; the margin of the vulva convex with a corona of fine setae.

Eureum ewingi Eichler

(Figure 9, 9A)

"*Ereum cimicoides* Nitzsch." Ewing, 1930. Proc. U. S. Nat. Museum, 77, no. 2843: p. 10, figs. 5 and 7e.
Eureum ewingi Eichler, 1942. Zool. Anz., 138: p. 179. *Nomen novum* for "*Eureum cimicoides* Nitzsch," Ewing, 1930 (*nec* Burmeister, 1838).

Type host: *Chaetura pelagica* (Linnaeus), Chimney Swift.

Ewing gave a complete description of a female collected at Columbus, Ohio, which he determined to be "*Eureum cimicoides* Nitzsch." Later Eichler noticed that Ewing's description did not agree with *Eureum cimicoides* Burmeister found on the type host. The specimen described by Ewing, which becomes the holotype, is still in the collection of Mr. H. S. Peters. Dr. Eichler did not see the specimen and based his action entirely on the information contained in Ewing's paper.

Mr. H. S. Peters has kindly loaned his specimen to the authors for this study. No additions need be made to Ewing's description, but the original illustrations are inadequate. Figure 5 (in Ewing, 1930) shows twelve setae on the posterior margins of the pronotum. There are only eight, four on each posterior lateral angle. The middle four setae of the drawing are not evident in the cleared, remounted type, nor are any sockets for these setae. The prosternal plate was incorrectly illustrated in figure 7e (Ewing 1930) and has been drawn as figure 9A. Mr. Chester J. Stojanovich has kindly illustrated the holotype as figure 9 and 9A.

Dr. G. J. Spencer, in 1947 (Proc. Ent. Soc. Br. Columbia, 44: p. 4) recorded "*Eureum cimicoides* Nitzsch" from *Nephoecetes niger borealis* (Kennerly, the Northern Black Swift, collected at Vancouver, British Columbia. This is the second and latest published record of a collection of this genus in North America. As noted by Dr. Spencer, the determination was made by Professor A. W. Baker. The material could not be secured for this study, so the identity of this series could not be established. In all probability, Spencer's (1947) material is not "*cimicoides*" but *E. spenceri* n. sp. described in this paper.

Eureum spenceri n. sp.
(Figures 10, 10A)

Male: Head twice is wide as long. Dorsal chaetotaxy of head as in *E. ewingi*, except for six long setae on each temple. Gular plate long and narrow, open posteriorly with nine long setae on each lateral margin. Pronotum with six long setae in each posterior lateral angle. Twenty-four or twenty-six short seta and six long setae on the prosternal plate. A patch of eight small stout setae on the first femora. Twenty-two short stout setae on the middle femora. A thick patch of short, fine setae on the last femora. One row of short and medium length setae on the posterior margin of each tergite. A row of medium-length setae on the posterior margin and a row of short setae on the anterior margin of the abdominal sternites. A patch of fine setae in the posterior lateral angles of abdominal sternites V, VI and VII. A patch of long setae in the posterior lateral angles of abdominal sternite VIII. Six short stout spines in the posterior lateral angles of abdominal sternites II, III and IV. Paratergal plates as in *E. ewingi*, except twice the number of spines and setae on each. Genital opening with a row of medium-length setae on the posterior margin. Anal opening with a sparse row of fine setae. Male genitalia as illustrated in figure 10A.

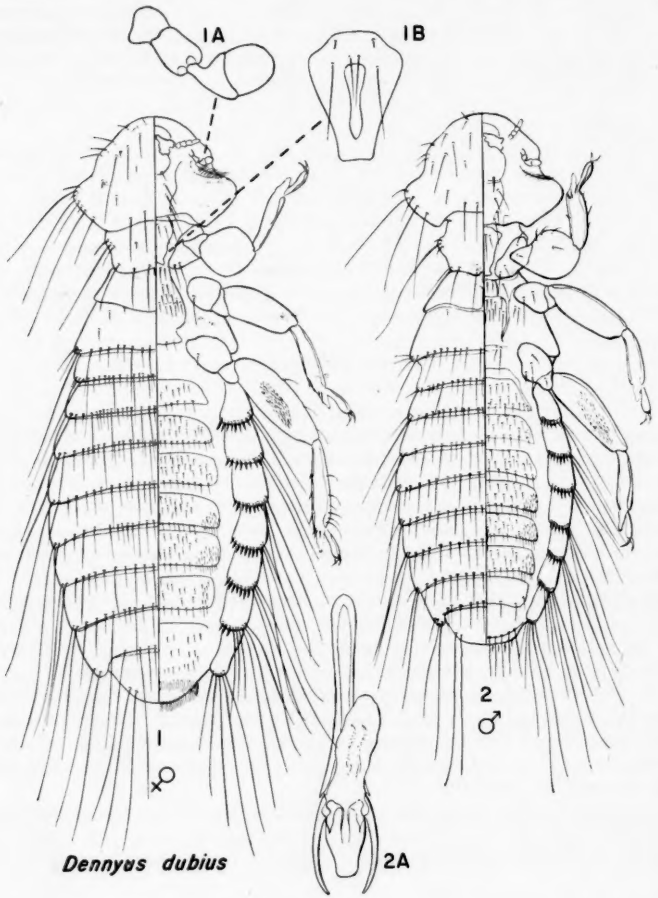
Female: General shape, size, and chaetotaxy, except for the terminal abdominal segments, same as in the male. Vulva broadly rounded, with six long setae in each posterior lateral angle. Posterior margins of anal corona with a

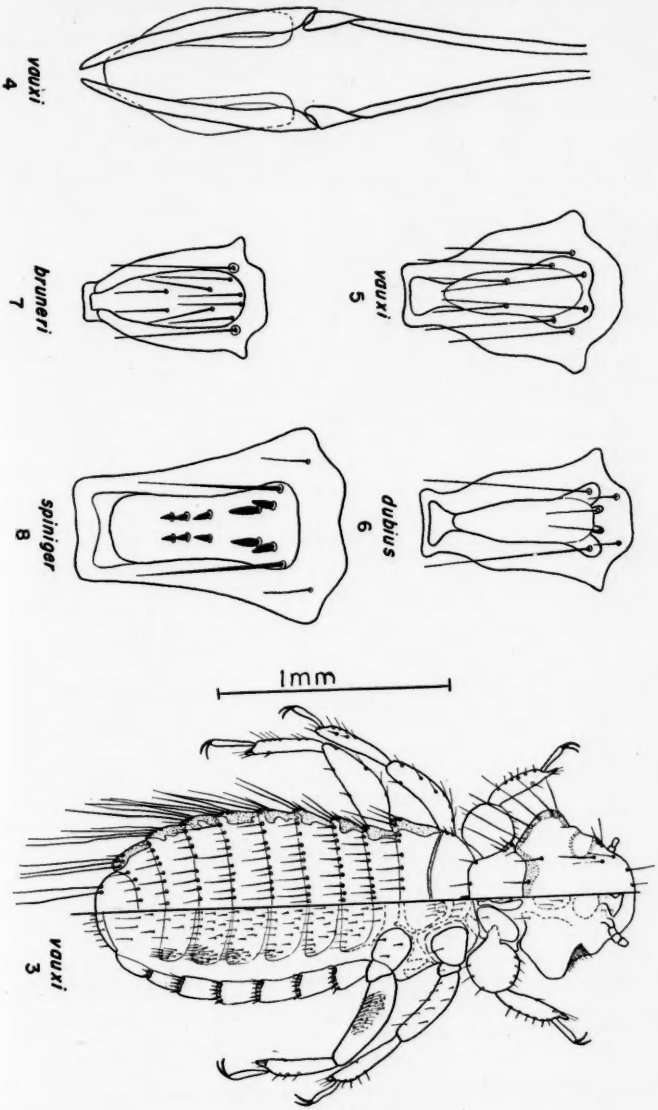
thick fringe of fine setae. Length of female and male is 4.4 mm. and greatest width in both sexes is 2.7 mm.

Type host: *Nephoecetes niger borealis* (Kennerly), Northern Black Swift.

Type material: Holotype male and two paratype males collected at New Denver, British Columbia, in May or June 1941 by Mr. J. Hatter. Allotype female collected at Vancouver, British Columbia, in November 1931 by Dr. G. J. Spencer. All types are in the collection of Dr. G. J. Spencer.

This species is closest to *E. ewingi,* but differs in being much larger and possessing a greater number of setae on the temples, pronotum, and paratergal plates.

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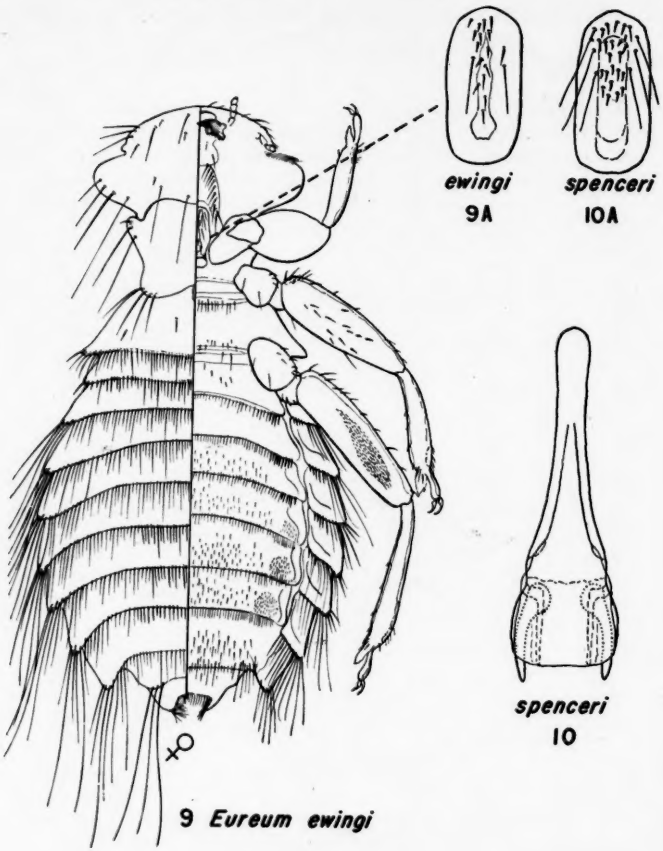

9 *Eureum ewingi*

EXPLANATION OF FIGURES

PLATE I

Dennyus dubius (Kellogg). 1. Dorsal-ventral view of female; 1A. antenna; 1B. prosternal plate; 2. dorsal-ventral view of male; 2A. male genitalia.

PLATE II.

Dennyus vauxi n. sp. 3. Dorsal-ventral view of male; 4. male genitalia; 5. prosternal plate.
Dennyus dubius (Kellogg). 6. Prosternal plate.
Dennyus bruneri (Carriker). 7. Prosternal plate.
Dennyus spiniger Ewing. 8. Prosternal plate.

PLATE III.

Eureum ewingi Eichler. 9. Dorsal-ventral view of female; 9A. prosternal plate.
Eureum spenceri n. sp. 10. Prosternal plate; 10A. male genitalia.

THE GENUS NEOTROMBIDIUM (ACARINA: TROMBIDIOIDEA) IN THE UNITED STATES[1]

J. G. BORLAND

The genus *Neotrombidium* contains a small group of little-known trombidioid mites which seem to be common in occurrence although rarely reported. The mites are easily identified in the adult stage by the form of the dorsal body setae, these being trident-shaped. Little is known of the other stages or of the life history.

The generic name was based on *Neotrombidium furcigerum* described by Leonardi in 1901. It was originally placed in the family Trombidiidae Leach, 1815. Added to the genus were *N. ophtalmicum* Berlese, 1912, and *N. barringunense* Hirst, 1928. These species were collected in Argentina, Paraguay, and Australia respectively, and all were described from the adult stage. Wharton (1938) described *Monunguis* (=*Neotrombidium*) *streblida* from the bat parasites, *Pterellipsis araneae* Coquillett and *Trichobius dugesii* Townsend (Diptera: Streblidae) from Yucatan, Mexico, and in a short note (1947) reported *Neotrombidium* adults and associated larvae from Duke Forest in North Carolina and suggested the synonymy of *Monunguis* with *Neotrombidium*. This is the only published record for the United States. Southcott (1954) described the reared larva of *N. barringunense*, noting certain aspects of its biology, and verified the synonymy of *Monunguis* with *Neotrombidium*.

The species from North Carolina is described below as *Neotrombidium tricuspidum* new species, on the basis of specimens taken in Kansas. In addition two larvae of a different new species were collected by Werner and Nutting on *Cymatodera peninsularis* (Coleoptera: Cleridae) in Brown's Canyon Baboquiveri Mts., Arizona, July 18, 1949. Thus the genus seems to be widespread in the United States.

Wharton (*in litt.*) has indicated doubt as to the synonymy of *Monunguis* with *Neotrombidium*. Upon examination of a coytype of *M. streblida*, it is the opinion of the writer that while recognition of the synonymy may be expedient at this time, as more data become available the two genera may be validly separated. At present, consolidation of this group appears desirable. Since *Monunguis* contains but the single species and no adult collections have been made, it lacks sufficient characters to warrant separation at the generic level. The larval scutum of *M. streblida* bears an incipient crista which is not present in known larvae of *Neotrombidium*, although upon careful comparison faint traces of the structure can be seen in *Neotrombidium*. Therefore, with respect to the scutum, *M. streblida* differs from *Neotrombidium* larvae in degree only. However, both the form of the setae and the body shape seem to set *M. streblida* apart from larvae of *Neotrombidium*. The setae, particularly those of the scutum, are much more plumose, bearing strong branches, and are more numerous on the dorsum than in either *N. tricuspidum* or *N. barringunense*, whose setae are sparse and with indistinct barbs. *Monunguis streblida* is pear-shaped, as opposed to the ovoid body form of *N. tricuspidum* and

[1] Contribution no. 909 of the Department of Entomology, University of Kansas, Lawrence.

N. barringunense. The cheliceral blades of *M. streblida* are peculiarly modified.

There appears to be ample argument for placing *Neotrombidium* in any one of three families. Womersley (1954) placed the genus in his family Leeuwenhoekiidae (Trombiculidae: Leeuwenhoekiinae of authors). Wharton (1947) retained the genus in Trombidiidae but noted some affinities with Trombiculidae. *Neotrombidium* was placed in Trombidiidae by Baker & Wharton (1952) but in the key given by these authors it will fall into Trombiculidae on the character of the paired tectal setae. This writer chooses to leave the genus unassigned until the taxonomy of related genera becomes better known, and until family levels are drawn along more definite lines.

In the following descriptions all measurements are given in microns. The larval description is based on the holotype with variations among the paratypes noted in parentheses. The terminology of Wharton, *et al.*, (1951), for trombiculids, has been followed wherever applicable. The description of the adult given below is somewhat perfunctory; the writer feels, however, that it is quite adequate for separating *N. tricuspidum* from other known adults, at least until a comprehensive study on the group is published.

Neotrombidium tricuspidum new species[2]

Description of larva. Diagnosis: Closely resembles *N. barringunense* but readily separable by the graduated branching of the coxal setae, the number and arrangement of body setae (particularly dorsal setae), and the three-toothed apex of the cheliceral blade. Easily separated from *M.* (=*N.*) *streblida* by the convex posterior margin of the scutum, absence of the incipient crista, more sparse setation, and the less strongly curved palpal claw.

Body: Color in life pinkish-orange, legs quite long and spiderlike, moves with slow deliberate steps. Body ovoid and somewhat elongate; length from scutal apex to tip of hysterosoma 346, width 176. Eyes, two on each side of scutum; situated on a distinct ocular plate, the anterior eye the larger and slightly stalked. Dorsal setal formula 6-4-6-2-2-2, total 22; ventral setal formula 2-2-2-2-4, total 12. Total body setae 34. Dorsal body seta measures 30, anterior ventral seta 26, subapical ventral seta 29. Dorsal setae heavy with tiny branches, ventral setae nude or nearly so. Four posterior ventral setae identical with dorsal setae.

Scutum: Shape roughly triangular, arms of triangle being concave above AL setae and base (posterior margin) being slightly convex. Scutal punctations large, numerous. Sensillae nude and filamentous. Scutal measurements of holotype: AW—55, PW—74, SB—52, ASB—81, PSB—18, AP—40, AM—28, AL—21, PL—18, S—74, AMB[3]—21. Averages and extremes of nine specimens (type series): AW—52(46-56), PW—77(74-81), SB—51(50-54), ASB—81(79-85), PSB—18(18-23), AP—39(35-42), AM—28(26-30), AL—21(20-23), PL—20(18-23), S—69(60-74), AMB—19(18-23).

Gnathosoma: Cheliceral blade slender, slightly curved, with three tooth-like projections on blunt apex; basal segment about four times as long as broad. Galeal seta short and branched. Palpal femur with one branched seta;

[2] Named for the three-toothed cheliceral apex of the larva.
[3] AMB: Distance between bases of anteromedian setae.

genu with one branched seta; tibia with three nude setae and a strongly bifurcate claw; tarsus with five or six nude setae and a basal tarsala.

Legs: Long in proportion to the body; bearing three types of setae: branched, short nude, and long nude (in addition to sensory "spurs"), as figured. Coxae I and II joined, bearing the urstigma between them; coxae I and III with a reticulate pattern in their lateral portions as illustrated. Coxa I with two setae, the inner long, whiplike, with small branches, measuring 40; this seta located on innermost coxal rim and possibly on venter in some specimens. Outer seta of coxa I with branches over its entire length, measuring 61; coxa II with one seta having branches on basal half, measuring 45; coxa III with one nude seta, measuring 46. Tarsus I with tarsala, microtarsala; tarsus II with tarsala, microtarsala. Tibia I with two tibialae, one microtibiala; tibia II with two tibialae; tibia III with one tibiala. Genu I with three genualae, one microgenuala; genu II with one genuala. Femur I with two femoralae; femur II with three femoralae; femur III with two femoralae. No sensory "spurs" found on other segments.

Description of adult female. Diagnosis: Closely resembles *N. barringunense,* but easily separated by having only one strong spine at base of palpal claw; tarsus I only twice as long as wide.

Body: Elongate, with distinct shoulders but without a distinct constriction between propodosoma and hysterosoma. Color in life red. Length, 1450; width, 547, in morphotype. Length of crista (morphotype) 188; nasus bearing a pair of branched but not three-tined tectal setae, posterior sensillary area bearing a pair of long filamentous sensillae finely barbed on the basal half and having fine ciliations on the apical half.[4] Distance between sensillary bases, 12. A pair of eyes on each side of the crista, situated on ocular plates, the posterior eye smaller, as figured. Body setae three-tined as illustrated, average 26 in length. Genital opening resembles that of *N. barringunense,* length quite variable, two pairs of genital suckers.

Gnathosoma: Cheliceral bases elongate; cheliceral blade sickle-shaped, inner edge of blade finely serrate as illustrated. Palpus resembling that of *N. barringunense;* tibia bearing a single strong spine at base of claw, as opposed to two or three such spines in *N. barringunense.* Palpal tarsus elongate, with basal striated tarsala, four apical nude setae, and other setae as illustrated. All setae on palpal tibia and tarsus nude.

Legs: Long, thin. All segments with punctae and branched setae. All coxae with reticulations resembling those found on the larval coxae I and III. Tarsus I measures 170 long, 83 wide in morphotype.

Type material. Holotype larva, K.U. slide no. 6846, and eight paratype larvae, nos. 6840-6845, 6847-6849, reared from adults, including morphotype female, no. 6849, and eight paratype females, nos. 6850-6856, taken March 16, 1954, beneath bark of standing dead black oak (*Quercus nigra*), in Douglas County, Kansas, one mile west, one-half mile north of Lecompton, by R. E. Beer, D. A. Crossley, Jr., and F. Madinger. Holotype larva, morphotype fe-

[4] It is possible that the barbed and ciliated structure of the sensillae is not unique for *N. tricuspidum,* but that it has merely escaped the notice of previous workers in the genus. The barbs and ciliations are discernible only under the oil immersion lens of a phase contrast microscope; otherwise the sensillae appear nude.

male, and paratypes are in the Snow Entomological Museum, University of Kansas. Paratypes will be sent to the United States National Museum, Washington, D.C.

Additional records: Kansas: Cherokee County, 3mi. S., 1 mi. E. Galena, April 7, 1955; two adult females collected by W. T. Atyeo and D. A. Crossley, Jr. North Carolina: Durham County, Duke Forest; adults collected by G. W. Wharton, larvae collected by Wm. Haliburton, both from fallen dead logs. Adults free, larvae parasitic on *Monochamus carolinensis* Oliv. (Coleoptera: Cerambycidae).

Culture data.—In March 1954 approximately 80 adult specimens from the type locality were placed in culture, using the Lipovsky (1953) method. It was observed that these specimens preferred a vertical surface to a horizontal one, since they would congregate in large numbers on a small drop of plaster on the side of a culture dish. After five days, during which only negative results were obtained (adults did not feed, no eggs were produced), a special culture tube was constructed, designed to give the mites a vertical surface on which to rest. The tube was constructed as follows: A ten-dram glass vial was ¾ filled with charcoal-plaster of paris mixture. Then five deep pits were made in the plaster with a needle at the margin of the vial, so that one wall of the pit was formed by the glass of the vial. Ten mites were placed in such a tube, which was then covered with paper to exclude light from the pits, thereby simulating the natural environment as nearly as possible. After five days in this tube, one adult died but the others began producing eggs.

The eggs are bright orange in color, oval and quite elongated, with rough irregular surfaces. They split longitudinally into equal halves upon hatching. Eggs and deutova resemble those figured by Southcott (1954) for *N. barringunense.*

An attempt was made to feed eight larvae on live specimens of *Creophilus maxillosus* Grav. (Coleoptera:Staphylinidae) and *Galerita janus* Fab. (Coleoptera:Carabidae). No positive results were obtained, but four larvae disappeared under the elytra of *G. janus* and were not recovered. It is possible that they attached and fed. Adults were kept in culture for 41 days, during which time there was no evidence that they fed. The only food materials offered them were eggs and active stages of the collembolan, *Sinella curviseta* Brook, which is an acceptable food for many species of trombiculid mites (Lipovsky, 1954).

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LITERATURE CITED

Baker. E. W. and G. W. Wharton. 1952, An Introduction to Acarology. 465 + xiv pp. Macmillan, New York.

Berlese. A. 1912. Trombidiidae. Redia 8:1-291.

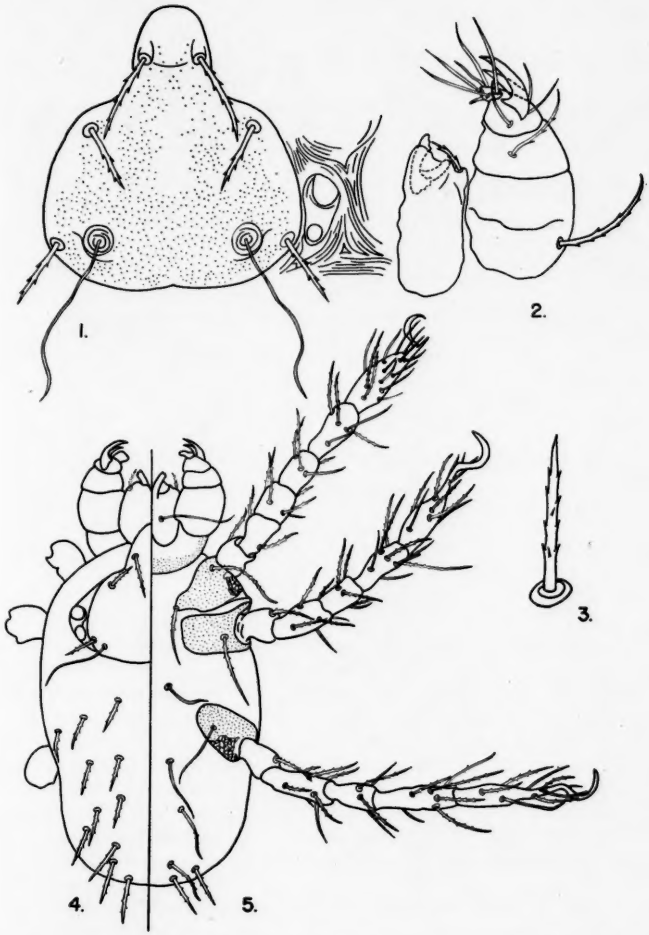

PLATE I. *Neotrombidium tricuspidum* n. sp., larva. 1, scutum and eyes; 2, dorsal aspect of gnathosoma; 3, dorsal body seta; 4, dorsal aspect of body; 5, ventral aspect of body, including legs.

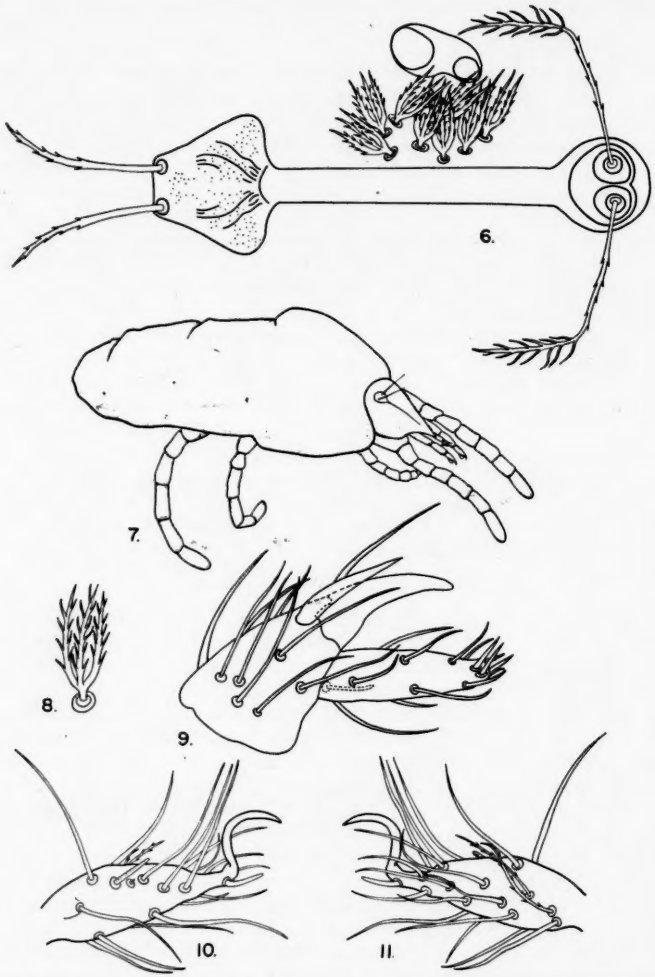

PLATE II. *Neotrombidium tricuspidum* n. sp., 6, crista and eyes, adult; 7, dorsolateral view of body of adult, unmounted specimen; 8, dorsal body seta, adult; 9, medial view of palpal tibia and tarsus, adult; 10, lateral view of tarsus of leg I, larva; 11, medial view of tarsus of leg I, larva.

Hirst, S. 1928. On some new Australian mites of the families Trombidiidae and Erythraeidae. Ann. Mag. Nat. Hist. (10) 1:563-571.
Leonardi, G. 1901. Acari sudamericani. Zool. Anz. 25:12-18.
Lipovsky, L. J. 1953. Improved technique for rearing chigger mites (Acarina: Trombiculidae). Ent. News 64:4-7.
———, 1954. Studies of the food habits of postlarval chiggers (Acarina: Trombiculidae). Univ. Kansas Sci. Bull. 36:943-958.
Southcott, R. V. 1954. The genus *Neotrombidium* (Acarina: Leeuwenhoekiidae). Description of the ovum and larva of *Neotrombidium barringunense* with an account of the biology of the genus. Trans. Roy. Soc. South Australia 77:89-97.
Wharton, G. W. 1938. Acarina of Yucatan caves. Carnegie Inst. Washington Pub. 491: 137-152.
———, 1947. The relationship between trombiculid and trombidiid mites. Jour. Parasit. 33 (supp. 2):15-16.
Wharton, G. W., D. W. Jenkins, J. M. Brennan, H. S. Fuller. G. M. Kohls, and C. B. Philip. 1951. The terminology and classification of trombiculid mites (Acarina: Trombiculidae). Jour. Parasit. 37:13-31.
Womersley, H. 1945. Acarina of Australia and New Guinea. The family Leeuwenhoekiidae. Trans. Roy. Soc. South Australia 69:96-113.
———, 1954. New genera and species, apparently of Apoloniinae (Acarina: Leeuwenhoekiidae), from the Asiatic-Pacific region. *in* Stud. Inst. Med. Res. Federation of Malaya. No. 26 (Malaysian Parasites), Kuala Lumpur, pp. 108-119.

NEW NAME FOR AN ECONOMIC WIREWORM (Coleoptera, Elateridae)

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An economic wireworm, probably introduced from South America, has been causing damage to Irish potatoes in the Southeastern States for several years. First reported by Lane (1953) and by Dobrovsky (1953), it has been found from Swan's Quarter, N.C., to New Orleans, La., in the Coastal Plain and Piedmont areas (Deen and Cuthbert, 1955). This new pest was described by Fall (1929) as *Monocrepidius difformis,* but this name is a homonym of a different species, *Monocrepidius difformis* Fleuteaux (1920) from Ecuador. Therefore, the new name of *Monocrepidius falli* is here proposed with type designation the same, namely, No. 24354 in Museum of Comparative Zoology at Cambridge, Mass., collected at Marlow, near Savannah, Ga., May 12, 1927 by G. R. Pilate. A comparison with specimens from South America in the United States National Museum shows this species to be identical with specimens labeled *Heteroderes vagus* Candèze (1893) from Buenos Aires. While the description of the latter seems to fit this new pest, the proof would have to await examination of the type in Europe. Both Schenkling (1925) and Van Dyke (1932) place *Monocrepidius* Esch. as a synonym of *Conoderus* Esch., while the first considers *Heteroderes* Latr. as distinct from *Conoderus,* the second considers it only a weak subgenus of same. If the latter is accepted then *H. vagus* Candèze (1893) is a homonym of *Monocrepidius vagus* Candèze (1888) from Burma. Under present nomenclature the name of this wire-

worm would be *Conoderus falli* with *M. difformis* Fall (1929) and probably *H. vagus* Candèze (1893) as synonyms.

Incidentally, a correction should be made in a previous article (Lane 1954) where *Heteroderes nicholsi* Notman (1922) was listed as a synonym of *Conoderus vagus* Cand. An examination of the type of *H. nicholsi* Notman in the American Museum of Natural History (New York) in June 1954 showed it to be a synonym of *Conoderus amplicollis* Gyll., another economic species known as the Gulf wireworm. This wireworm (*Conoderus falli*) might be given the common name "Southern potato wireworm."

Publications referring to *Conoderus vagus* Cand. and *difformis* Fall:

Candeze, E. 1888. Elaterides recueillis en Birmanie et au Tenasserim. Ann Mus. Genova (2) 6:674.

———, 1893. Elaterides nouveaux. Fasc. 5, Mem. Soc. Liege (2) 18:32.

Deen, O. T., and F. P. Cuthbert, Jr. 1955. Distribution and relative abundance of wireworms in potato-growing areas of the Southwestern States. Jour. Econ. Ent. 48 (2):191.

Dobrovsky, T. M. 1953. Another wireworm of Irish potatoes. Jour. Econ. Ent. 46 (6):1115.

Fall, H. C. 1929. New Coleoptera. XIII. Canad. Ent. 61:56.

Fleuteaux, E. 1920. Elaterides. Bull. Mus. Nat. Hist. Paris 26(4):302.

Lane, M. C. 1953. Distribution of the wireworm *Conoderus vagus* Cand. U. S. Bur. Ent. and Plant Quarantine, Coop. Econ. Insect Rpt. 3 (29):536.

———, 1954. Distribution of several introduced species of wireworms. U. S. Plant Pest Control Branch, Coop. Econ. Insect Rpt. 4 (12):243.

Notman, H. 1922. New species of Coleoptera. Bull. Brooklyn Ent. Soc. 17:107.

Schenkling, S. 1925. Coleopterorum Catalogus (Junk) Pars. 80, p. 105.

Van Dyke, E. C. 1932. Misc. Studies in the Elateridae, and related families. Proc. Calif. Acad. Sc., (4) 20 (9):294.

Errata. In the article by Paul T. Riherd and George P. Wene on moths captured at a light trap at Westlaco, Texas which appeared in the July issue of this journal (1955), the species listed on page 106 as *Panula inconstans* Gn. should be listed as *Melipotis cellaris* Gn.

Editor.

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